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Okita

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(54) **METHOD AND APPARATUS TO TRANSFER FILE DATA TO A CLOUD ENVIRONMENT**

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G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/30073*** (2013.01); ***G06F 17/302*** (2013.01); ***G06F 17/30197*** (2013.01)

(58) **Field of Classification Search**
USPC 707/748, 827
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0187910 A1* 8/2006 Franz et al. 370/389
2008/0101396 A1* 5/2008 Miyata 370/408
2009/0028169 A1* 1/2009 Bear et al. 370/406
2009/0041039 A1* 2/2009 Bear et al. 370/401
2009/0069642 A1* 3/2009 Gao et al. 600/300
2009/0129264 A1* 5/2009 Bugenhagen et al. 370/230
2009/0233610 A1* 9/2009 Paetsch 455/445
2010/0333116 A1 12/2010 Prahlad et al.
2011/0170555 A1* 7/2011 Miyata 370/401
2013/0010621 A1* 1/2013 Yoshiuchi et al. 370/252
2013/0212214 A1* 8/2013 Lawson et al. 709/217
2013/0286830 A1* 10/2013 Xu et al. 370/232

* cited by examiner

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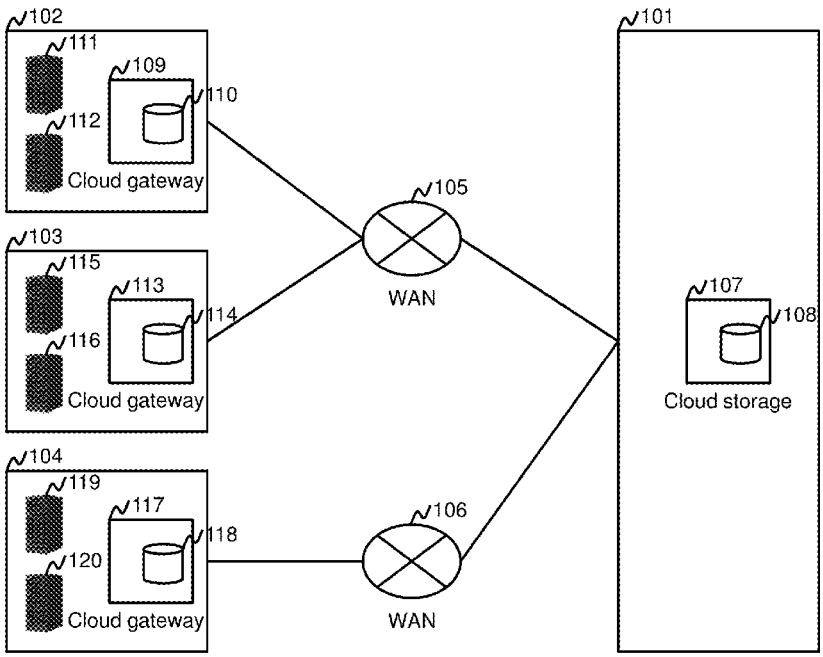
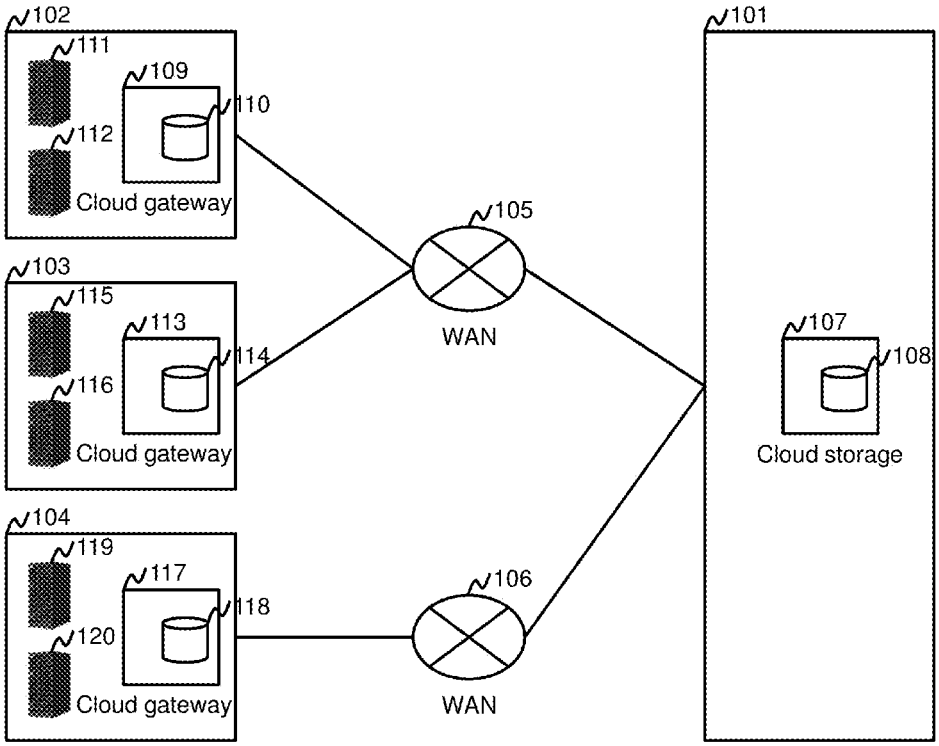
(57) **ABSTRACT**

Systems and methods are directed to a file storage system that manages configuration information for each cloud gateway's storage device. Systems and methods also manage a configuration parameter; and a file transfer slot number, which represents how many HTTP sessions the cloud gateway can process substantially simultaneously. Based on the configuration information, systems and methods may prioritize the multiple cloud gateways. Systems and methods calculate time lengths weighted by the priorities of the cloud gateways and multiplied by the file-transfer slot number for each cloud gateway in a time period, and then allocate time slots of the cloud gateways in the time period according to the above calculated time lengths. Systems and methods therefore allow for automatically aligning the traffic between cloud gateways and cloud storage according to the configuration of cloud gateways.

15 Claims, 16 Drawing Sheets

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111
109
110
112
Cloud gateway
103
115
113
114
116
Cloud gateway
104
119
117
118
120
Cloud gateway
105
WAN
106
WAN
101
107
108
Cloud storage

Fig. 1

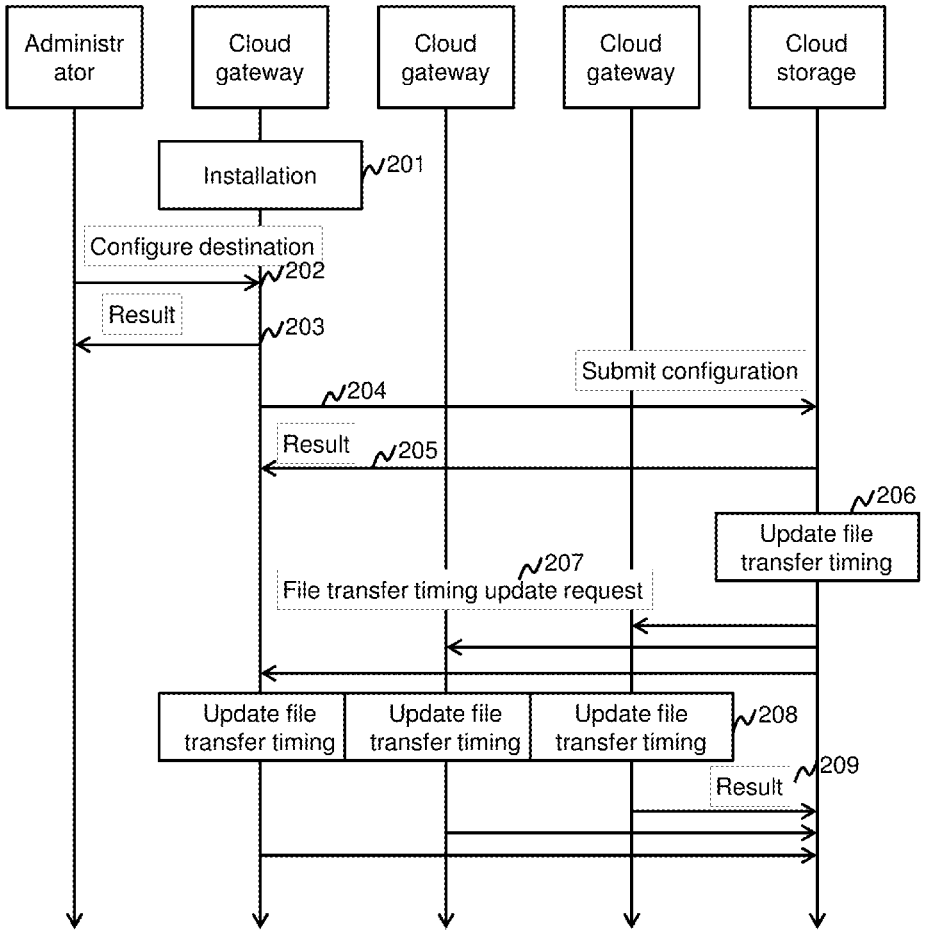
Administr ator
Cloud gateway
Cloud gateway
Cloud gateway
Cloud storage
Installation
201
Configure destination
202
Result
203
Submit configuration
204
Result
205
206
Update file transfer timing
207
File transfer timing update request
Update file transfer timing
Update file transfer timing
Update file transfer timing
208
209
Result

Fig. 2

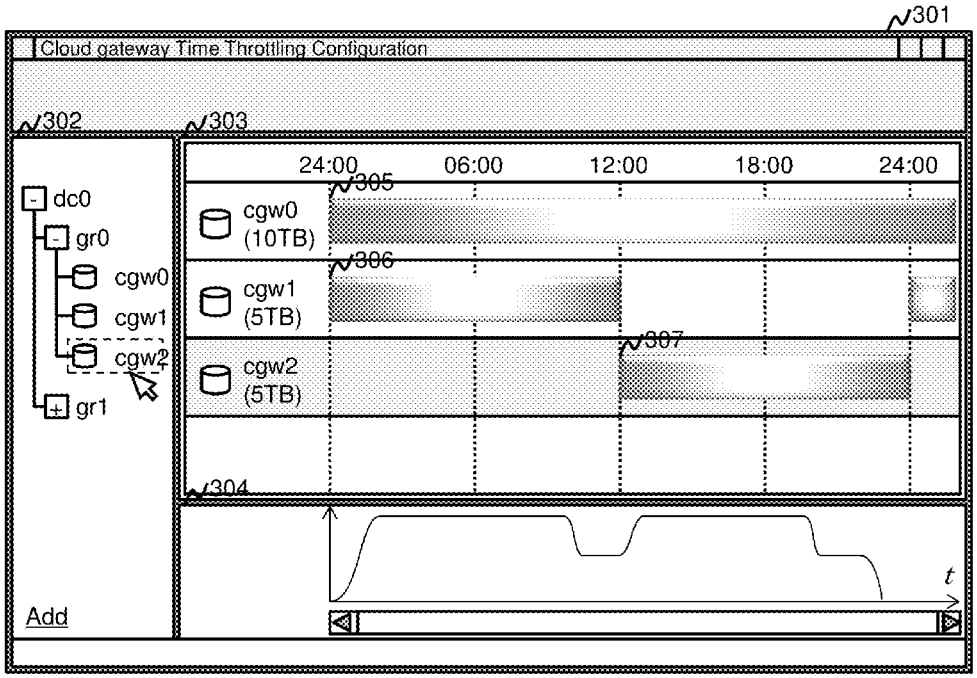
301
Cloud gateway Time Throttling Configuration
302
303
24:00
06:00
12:00
18:00
24:00
dc0
gr0
cgw0
cgw1
cgw2
gr1
305
cgw0
(10TB)
306
cgw1
(5TB)
307
cgw2
(5TB)
304
t
Add

Fig. 3

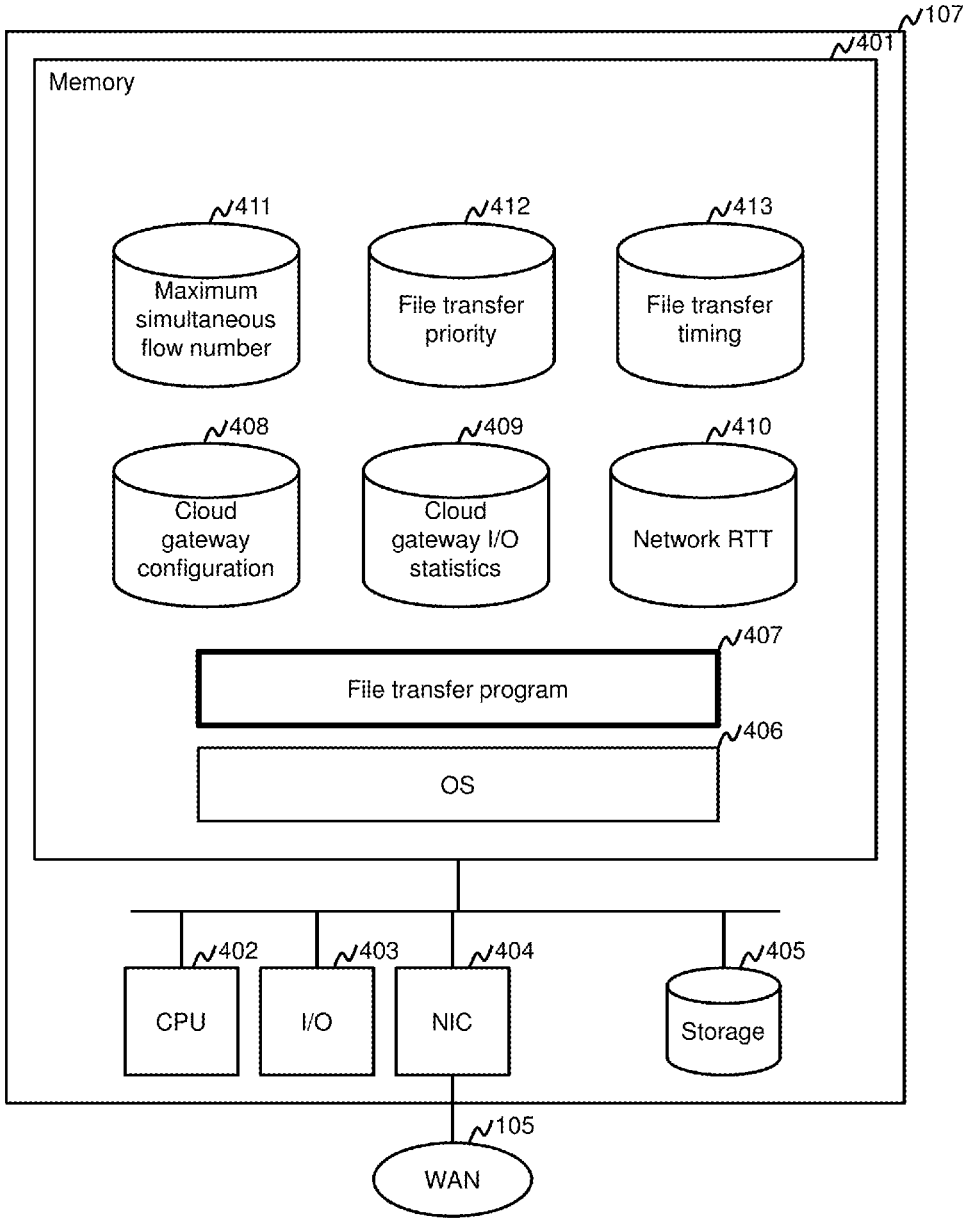
107
401
Memory
411
Maximum simultaneous flow number
412
File transfer priority
413
File transfer timing
408
Cloud gateway configuration
409
Cloud gateway I/O statistics
410
Network RTT
407
File transfer program
406
OS
402
CPU
403
I/O
404
NIC
405
Storage
105
WAN

Fig. 4

Cloud gateway configuration information

408

Cloud gateway ID	Volume	Size	Archive	
cgw0	Vol00	5TB	Yes	501
cgw0	Vol01	5TB	Yes	502
cgw0	Vol02	10TB	No	503
cgw1	Vol11	5TB	Yes	504
cgw2	Vol21	5TB	Yes	505

Fig. 5

Cloud gateway I/O statistics information

409

Cloud gateway ID	Read GB/day	Write GB/day
cgw0	0.2	1.0
cgw1	0.1	0.5
cgw2	0.1	0.5

601
602
603

Fig. 6

Network RTT information

410

Cloud gateway ID	RTT
cgw0	10 ms
cgw1	10 ms
cgw2	20 ms

701
702
703

Fig. 7

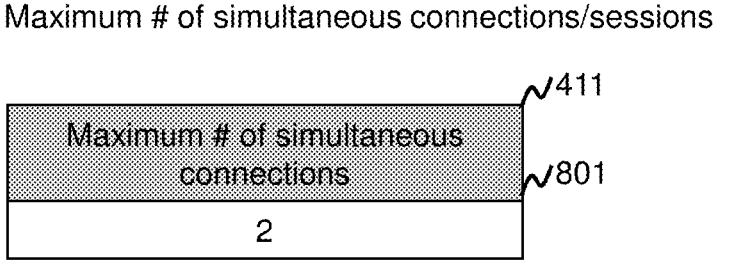
Maximum # of simultaneous connections/sessions
411
Maximum # of simultaneous connections
801
2

Fig. 8

File transfer priority information

412

Cloud gateway ID	Priority
cgw0	100
cgw1	50
cgw2	50

901
902
903

Fig. 9

File transfer timing information

413

Cloud gateway ID	Allocated time	Start time	End time	
cgw0	24 hrs	00:00	24:00	1001
cgw1	12 hrs	00:00	12:00	1002
cgw2	12 hrs	12:00	24:00	1003

Fig. 10

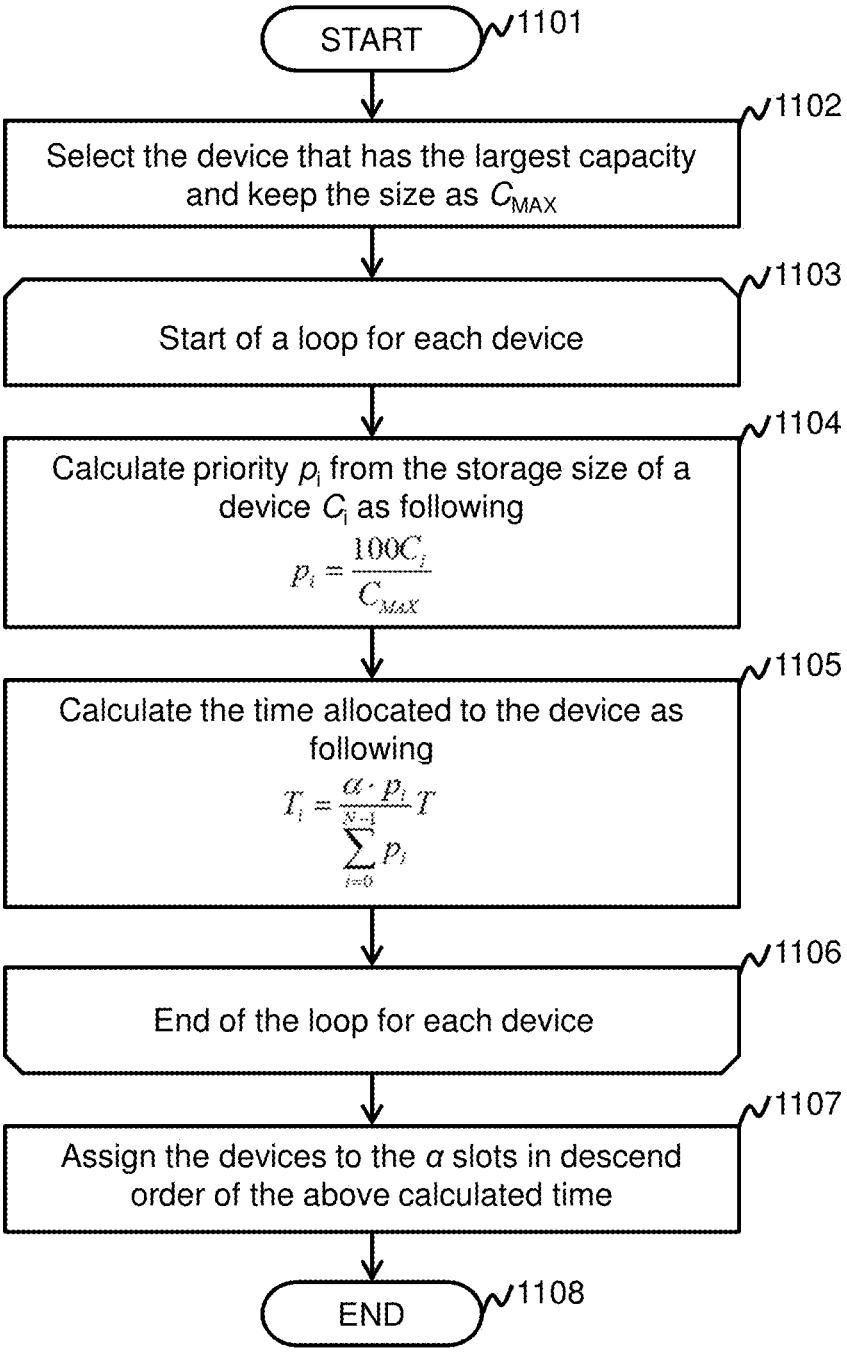
START
1101
Select the device that has the largest capacity and keep the size as C_{MAX}
1102
Start of a loop for each device
1103
Calculate priority p_i from the storage size of a device C_i as following
$p_i = \frac{100C_i}{C_{MAX}}$
1104
Calculate the time allocated to the device as following
$T_i = \frac{\alpha \cdot p_i}{\sum_{i=0}^{N-1} p_i} T$
1105
End of the loop for each device
1106
Assign the devices to the α slots in descend order of the above calculated time
1107
END
1108

Fig. 11

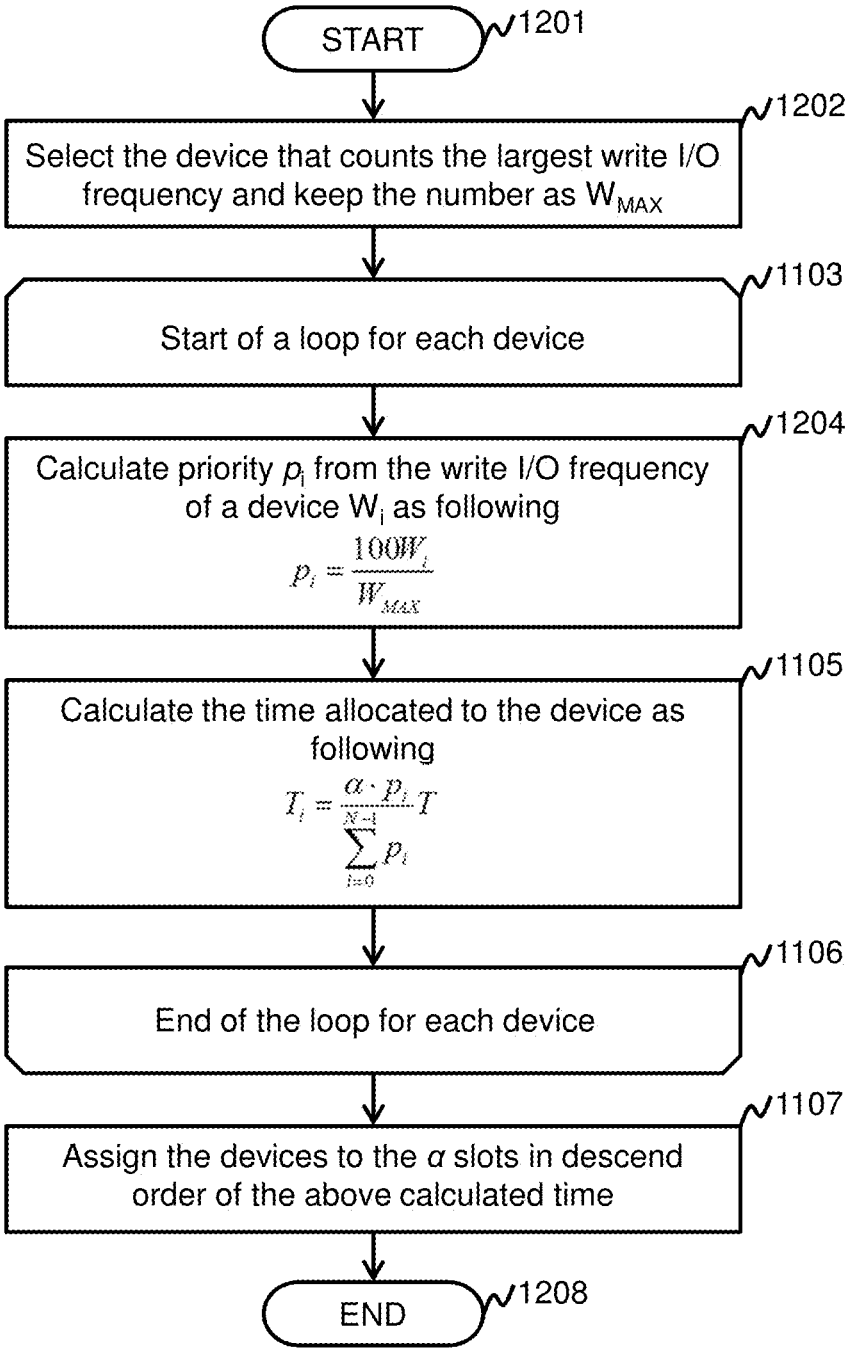
START
1201
Select the device that counts the largest write I/O frequency and keep the number as W_{MAX}
1202
Start of a loop for each device
1103
Calculate priority p_i from the write I/O frequency of a device W_i as following
$p_i = \frac{100W_i}{W_{MAX}}$
1204
Calculate the time allocated to the device as following
$T_i = \frac{\alpha \cdot p_i}{\sum_{i=0}^{N-1} p_i} T$
1105
End of the loop for each device
1106
Assign the devices to the α slots in descend order of the above calculated time
1107
END
1208

Fig. 12

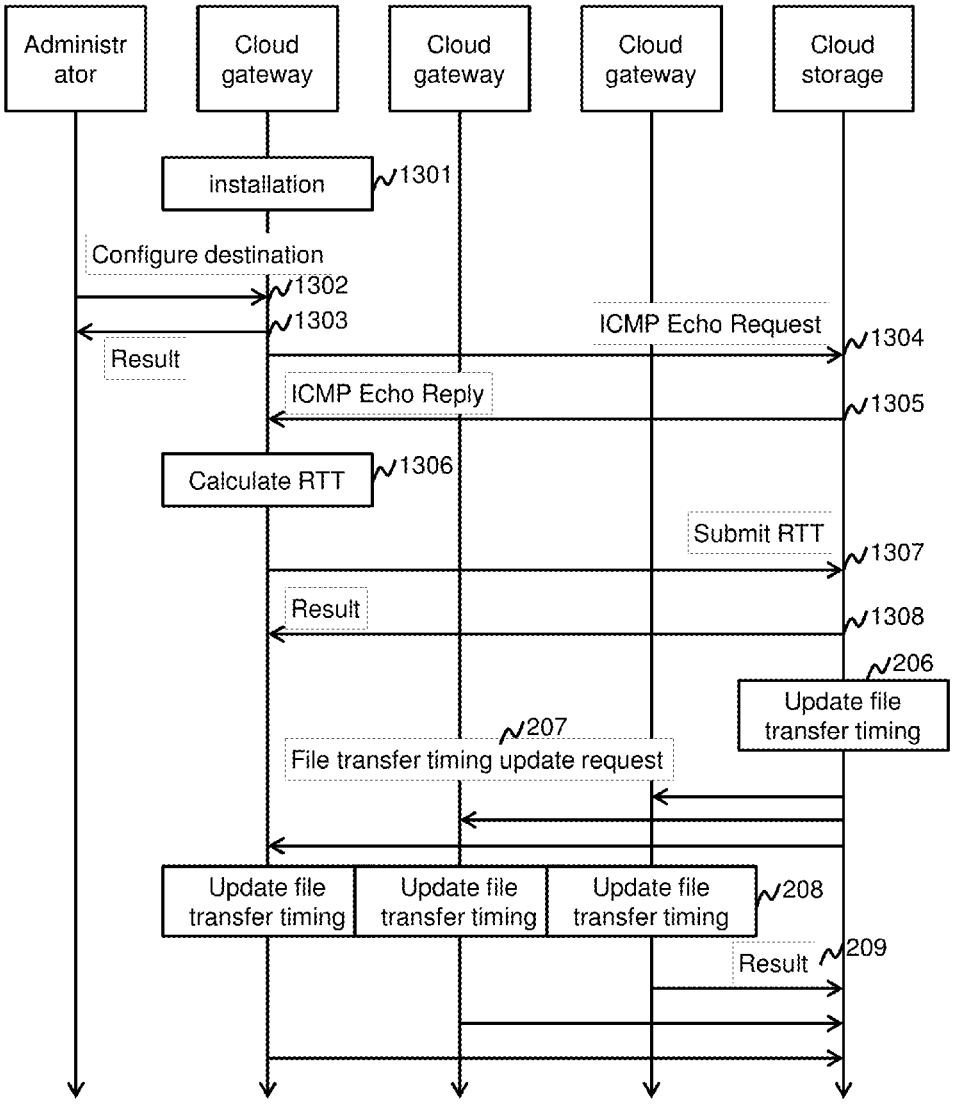
Administr ator
Cloud gateway
Cloud gateway
Cloud gateway
Cloud storage
installation
1301
Configure destination
1302
1303
Result
ICMP Echo Request
1304
ICMP Echo Reply
1305
Calculate RTT
1306
Submit RTT
1307
Result
1308
206
Update file transfer timing
207
File transfer timing update request
Update file transfer timing
Update file transfer timing
Update file transfer timing
208
Result
209

Fig. 13

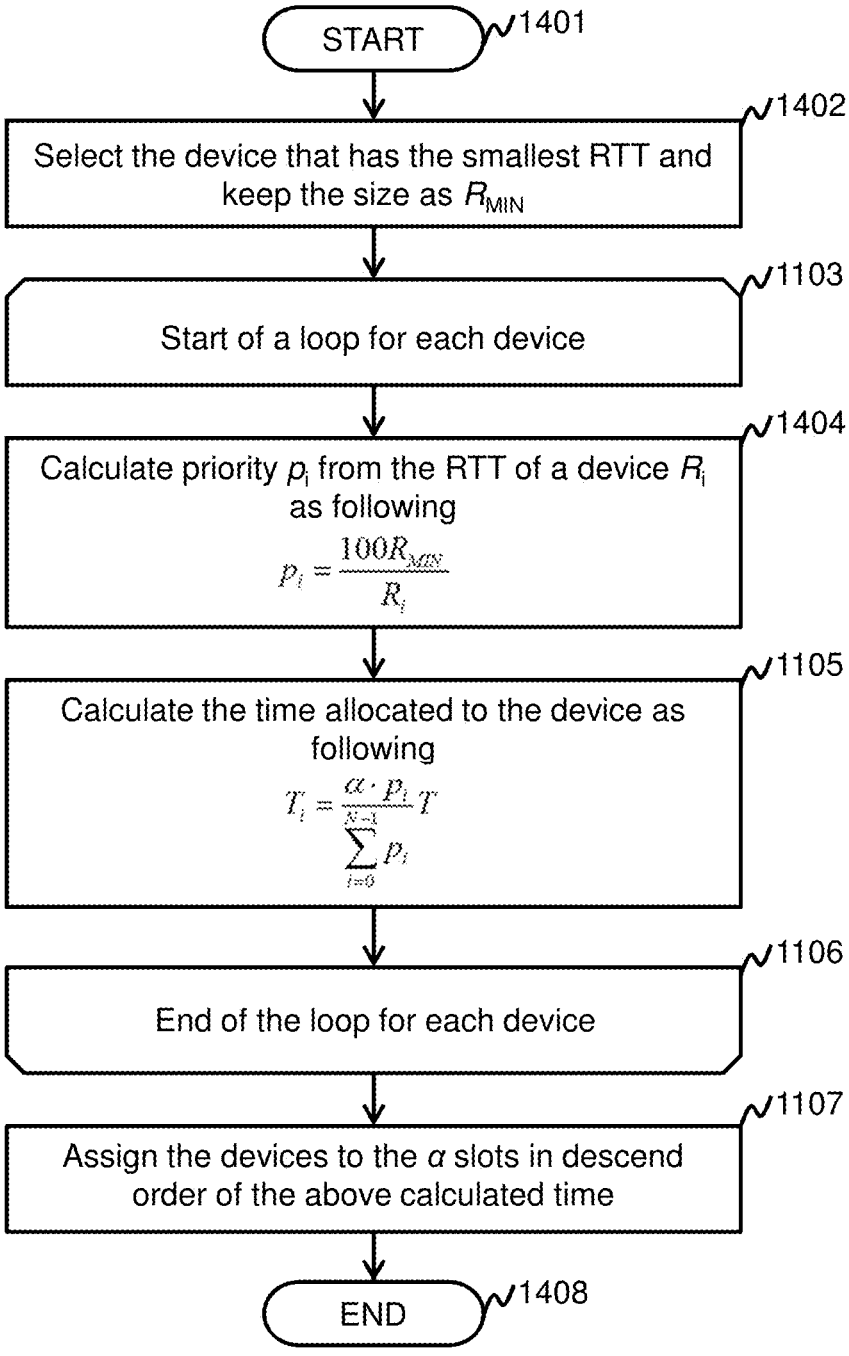
START
1401
Select the device that has the smallest RTT and keep the size as R_{MIN}
1402
Start of a loop for each device
1103
Calculate priority p_i from the RTT of a device R_i as following
$p_i = \frac{100R_{MIN}}{R_i}$
1404
Calculate the time allocated to the device as following
$T_i = \frac{\alpha \cdot p_i}{\sum_{i=0}^{N-1} p_i} T$
1105
End of the loop for each device
1106
Assign the devices to the α slots in descend order of the above calculated time
1107
END
1408

Fig. 14

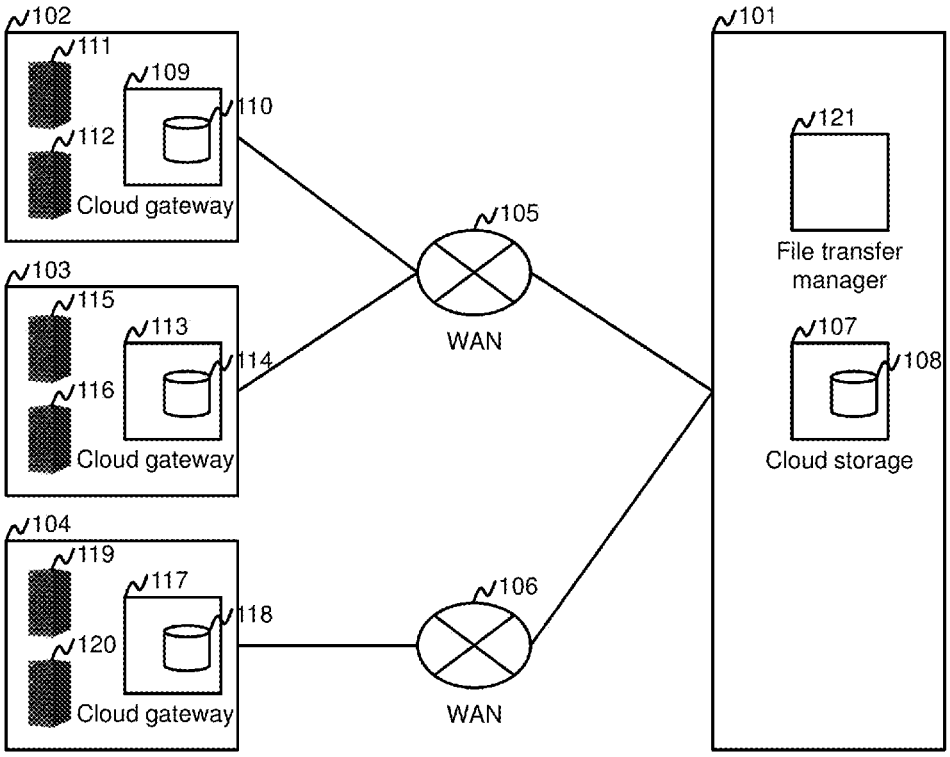
102
111
109
110
112
Cloud gateway
103
115
113
114
116
Cloud gateway
104
119
117
118
120
Cloud gateway
105
WAN
106
WAN
101
121
File transfer manager
107
108
Cloud storage

Fig. 15

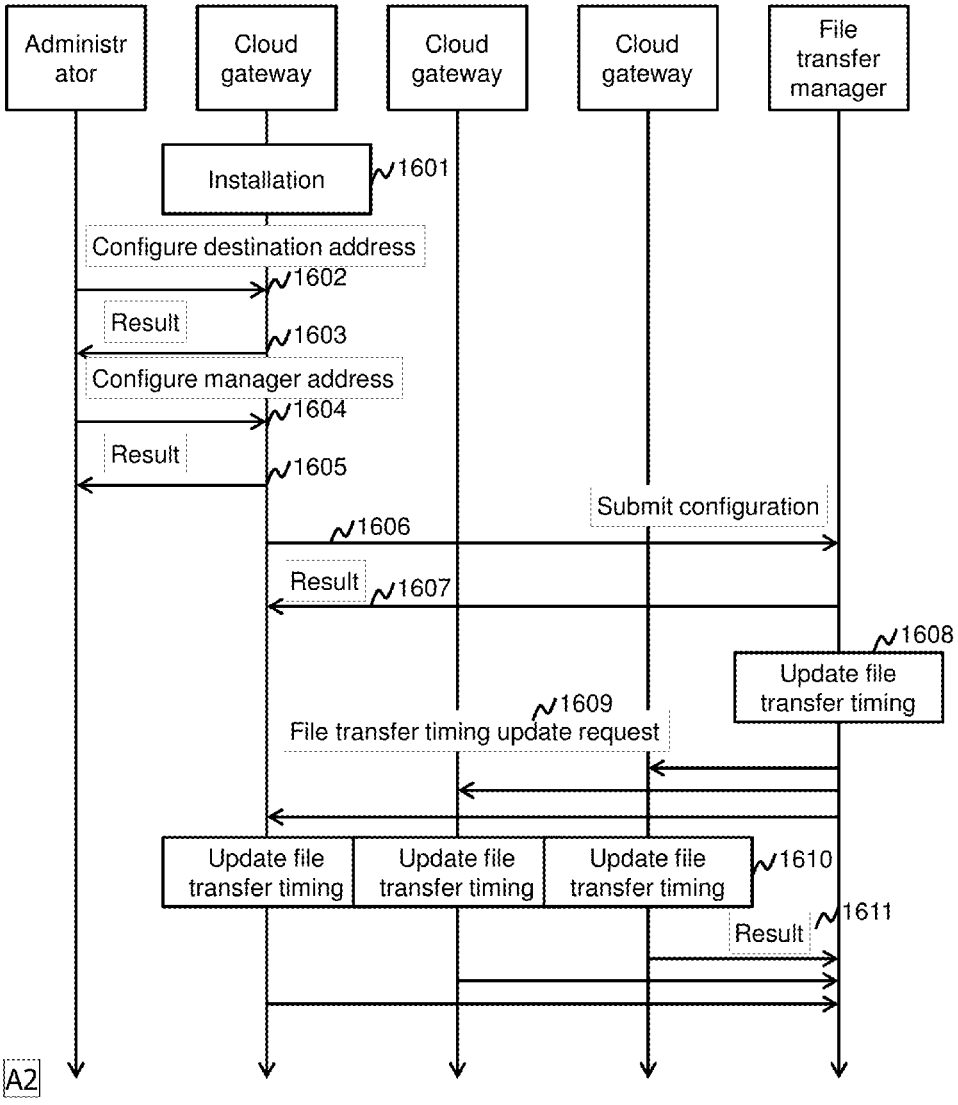
Administr ator
Cloud gateway
Cloud gateway
Cloud gateway
File transfer manager
Installation
1601
Configure destination address
1602
Result
1603
Configure manager address
1604
Result
1605
Submit configuration
1606
Result
1607
1608
Update file transfer timing
1609
File transfer timing update request
Update file transfer timing
Update file transfer timing
Update file transfer timing
1610
1611
Result
A2

Fig. 16

METHOD AND APPARATUS TO TRANSFER FILE DATA TO A CLOUD ENVIRONMENT

BACKGROUND

1. Technical Field

Methods and example implementations described herein are generally directed to storage area network (SAN) storage systems, and specifically, for cloud storage systems.

2. Related Art

Network Attached Storage (NAS) systems are emerging in the enterprise IT (Information Technology) systems to store unstructured data files (e.g., document, figures, voice, movie, etc.). By using the NAS, enterprise users can share the unstructured data files on their enterprise computer network. The NAS uses standard file access protocols such as the Network File System (NFS) protocol or the Common Internet File System (CIFS) protocol to receive file read/write requests from their client computers and to reply the requested files. NAS systems can be implemented in a cloud, where storage and other functions are stored in one or more outside servers rather than on the client device.

In view of the extensibility of the network attached storage system, the related art cloud storage system was developed. The cloud storage system may include a set of one or multiple cloud gateways and one or multiple cloud storage devices. The cloud gateways are located in user sites and act as general NAS devices. Such cloud storage devices are located in external sites such as remote sites of the users or cloud services. The cloud gateways transfer the file data stored in them to the cloud storage devices according to their configurations. For example, when the total size of data stored in a cloud gateway exceeds the pre-configured threshold for total data size, the cloud gateway transfers the least accessed file into a cloud storage device that is designated as a target device for the cloud gateway. The cloud storage device then keeps mapping information between the metadata of the transferred file and the actual location of the file.

However, when the number of the cloud gateways that designate the same cloud-storage device increases, the throughput of the cloud storage device will decrease. The multiple Hyper Text Transfer Protocol/Hyper Text Transfer Protocol Secure (HTTP/HTTPS) sessions may cause congestion in a network between the cloud gateways and the cloud-storage device. The congestion reduces data transfer rate of the HTTP sessions due to the congestion control mechanism of the Transmission Control Protocol (TCP) layer. As a result, the total throughput of the cloud-storage device is reduced. Also, the multiple overlapped HTTP sessions may exhaust HTTP processing capacity of the cloud-storage device. Thus, in the same way, throughput of the cloud-storage device will be reduced.

SUMMARY

Aspects of the present application may include a storage system communicatively coupled to a plurality of cloud gateways via a network, and configured to transfer data via the cloud gateways. The storage system may involve a management unit; and a memory configured to store information for each of the plurality of cloud gateways; wherein the management unit determines a priority for each cloud gateway based on the information.

Aspects of the present application may include a computer readable storage medium storing instructions for executing a process. The instructions may involve storing information of each of a plurality of cloud gateways; and determining a priority for each of the plurality of cloud gateways based on the information.

Aspects of the present application may include a method for managing a plurality of cloud gateways, which can involve storing information of each of a plurality of cloud gateways; and determining a priority for each of the plurality of cloud gateways based on the information.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example of a network with a file storage system, in accordance with an example implementation.

FIG. **2** illustrates an example of a message sequence of a file storage system, in accordance with an example implementation.

FIG. **3** illustrates an example of a user interface of a file storage system, in accordance with an example implementation.

FIG. **4** illustrates an example of hardware and software architecture of the cloud storage of a file storage system, in accordance with an example implementation.

FIG. **5** illustrates an example of the structure of the cloud gateway configuration information of the cloud storage in a file storage system, in accordance with an example implementation.

FIG. **6** illustrates an example of the structure of the file I/O statistics information of the cloud storage of a file storage system, in accordance with an example implementation.

FIG. **7** illustrates an example of the structure of the network Round Trip Time (RTT) information of a file storage system, in accordance with an example implementation.

FIG. **8** illustrates an example implementation of the structure of the file transfer slot number of a file storage system, in accordance with an example implementation.

FIG. **9** illustrates an example of the structure of the file transfer priority information of a file storage system, in accordance with an example implementation.

FIG. **10** illustrates an example of the structure of the file transfer timing information of a file storage system, in accordance with an example implementation.

FIG. **11** illustrates an example of a flow diagram of the file transfer program of the cloud storage of a file storage system, in accordance with an example implementation.

FIG. **12** illustrates an example of the flow diagram of the file transfer program in a second example implementation of a file storage system.

FIG. **13** illustrates an example of a message sequence in a third example implementation of a file storage system.

FIG. **14** illustrates an example of the flow diagram of the file transfer program in a third example implementation of a file storage system.

FIG. **15** illustrates an example of a network in a fourth example implementation of a file storage system.

FIG. **16** illustrates an example of a message sequence in a fourth example implementation of a file storage system.

DETAILED DESCRIPTION

The example implementations described herein attempt to address the above described problems of the related art, and to improve the total throughput of the cloud-storage device having a large number of cloud gateways.

Related art storage systems have a problem that as the number of cloud gateways in the system increases, the throughput growth of the cloud storage is suppressed due to

congestion of multiple Hyper Text Transfer Protocol (HTTP) sessions in a network and exhausting the cloud storage's capacity of HTTP/TCP communication. To address the problem, example implementations of the present application provide a file storage system that manages configuration information for each cloud gateway's storage device. The example implementations also manage a configuration parameter; and a file transfer slot number, which represents how many HTTP sessions the cloud gateway can process simultaneously. Based on the configuration information, example implementations prioritize the multiple cloud gateways. The example implementations calculate time lengths weighted by the priorities of the cloud gateways and multiplied by the file-transfer slot number for each cloud gateway in a time period, and then allocate time slots of the cloud gateways in the time period according to the above calculated time lengths. The example implementations therefore allow for automatically aligning the traffic between cloud gateways and cloud storage according to the configuration of cloud gateways.

First Example Implementation

Storage Size Based Time Slot Allocation

In a first example implementation, a storage system is configured to allocate a time slot for each cloud gateway based on a size of a storage component of each cloud gateway.

FIG. **1** illustrates an example of a network with a file storage system, in accordance with an example implementation. The system may include a cloud-storage (e.g. storage system) **107**, client sites **102**, **103**, **104** and cloud site **101**. The system may also include one or multiple cloud gateways **109**, **113**, and **117**. The cloud-storage and gateways are connected each other by wide-area networks (WANs) **105**, and **106**. The cloud storage and gateways have internal storage components **108**, **110**, **114**, and **118**. User clients **111**, **112**, **115**, **116**, **119**,**120** are located in user sites closer to the cloud gateways **109**, **113**, and **117**.

FIG. **2** illustrates an example of a message sequence of file storage system, in accordance with an example implementation. After an administrator of the system installs the third cloud gateway **117** to the system (**201**), the administrator configures the destination of the file transfer by the cloud gateway **117** (**202**) and obtain the result of the configuration (**203**). Then, the cloud gateway **117** starts the submission process. The cloud gateway **117** sends a message to submit the cloud gateway's configuration information including the total size of its internal storage devices, to the cloud storage **107** (**204**). Cloud gateway **117** then receives the result of the submission (**205**).

The cloud storage may operate as a management unit in an example implementation. For example, the cloud storage **107** updates the file transfer timing according to the information about cloud gateway storage size (**206**). The cloud storage **107** sends requests to the cloud gateways that require file transfer timing to the cloud storage **107** (**207**). The cloud gateways that receive the request update their file-transfer timing (**208**). Finally, the cloud storage **107** receives the update results of their file-transfer timing (**209**).

FIG. **3** illustrates an example of a user interface of a file storage system, in accordance with an example implementation. FIG. **3** illustrates a list of managed cloud gateways in a left pane **302**, as well as time slots allocated for each of the cloud gateways **109**, **113**, and **117** in the upper-right side pane **303**. FIG. **3** also illustrates the transition of the actual traffic amount the cloud storage **107** has received in the lower-right side pane **304**. In the pane **303**, rows show time slots **305**~**307** allocated for the cloud gateways.

FIG. **4** illustrates an example of hardware and software architecture of the cloud storage **107** of a file storage system, in accordance with an example implementation. The cloud storage **107** may involve a memory **401**, a central processing unit (CPU) **402**, an input/output unit (I/O) **403**, a network interface controller (NIC) **404**, and an internal storage **405**. The memory **401** stores an operating system (OS) **406** and a file transfer program **407**. The memory also stores cloud gateway configuration information **408**, cloud gateway I/O statistics **409**, network RTT information **410**, and maximum simultaneous flow number information **411**, file transfer priority information **412**, and file transfer timing information **413**. The NIC **404** is connected to the WAN **105** and **106**.

The file transfer program **407** enables the cloud storage **107** to work as an HTTP-based object storage that receives file transferred from the cloud gateways **109**, **113**, and **117**.

The memory may be in the form of a computer readable storage medium that stores instructions for executing a process. Computer readable storage mediums include tangible storage medias such as random access memory (RAM), Hard Disk Drive (HDD), CD/DVDs, flash memory and the like. Alternatively, the elements as illustrated in memory **401** may be stored in a computer readable signal medium instead of a memory **401**, which may include non-tangible storage media such as carrier waves.

FIG. **5** illustrates an example of the structure of the cloud gateway configuration information **408** of the cloud storage **107** in a file storage system, in accordance with an example implementation. The cloud gateway configuration information **408** is implemented as a table. Each row **501**~**505** of the table **408** represents a storage volume **110**, **114**, or **118** of a cloud gateway **109**, **113**, or **117**. Each row **501**~**505** may include an identifier of a cloud gateway, an identifier of a storage volume, a size of the storage volume, and a flag of the status of archiving feature.

The cloud storage **107** can utilize the cloud gateway configuration information to manage the configuration of storage volumes **110**, **114**, and **118** of respective cloud gateways **109**, **113**, and **117** as reference information for calculating the priorities for each cloud gateway **109**, **113**, and **117**.

FIG. **6** illustrates an example of the structure of the file I/O statistics information **409** of the cloud storage **107** of a file storage system, in accordance with an example implementation. In the example of FIG. **5**, the cloud gateway I/O statistics information **409** is implemented as a table. Each row **601**~**603** of the table **409** represents a cloud gateway **109**, **113**, or **117**. Each row **601**~**603** may include an identifier of a cloud gateway **109**, **113**, or **117**, the total amount of data that the corresponding cloud gateway **109**, **113**, or **117** has read from the cloud storage **107** during a past day, and the total amount of data that the corresponding cloud gateway **109**, **113**, or **117** has written into the cloud storage **107** during a past day.

The cloud storage **107** can utilize the file I/O statistics information to manage the cloud gateway I/O statistics of cloud gateway **109**, **113**, or **117** as reference information for calculating priorities for each cloud gateway **109**, **113**, **117**.

FIG. **7** illustrates an example of the structure of the network Round Trip Time (RTT) information **410** of a file storage system, in accordance with an example implementation. The network RTT information **410** is implemented as a table. Each row **701**~**703** of the table **410** represents a cloud gateway **109**, **113**, or **117**. Each row **701**~**703** may include an identifier of a cloud gateway **109**, **113**, or **117**, a round-trip

time (RTT) between a correspond cloud-gateway **109**, **113**, or **117** and the cloud storage **107**.

The cloud storage **107** can utilize the RTT information to manage the network RTT for each cloud gateway **109**, **113**, or **117** as reference information for calculating priorities for each cloud gateway **109**, **113**, or **117**.

FIG. **8** illustrates an example implementation of the structure of the file transfer slot number of a file storage system, in accordance with an example implementation. The file transfer slot number is implemented as a variable **801** and stores an integer. The stored integer indicates the maximum number of HTTP connections/sessions that the cloud storage **107** can process simultaneously with the cloud gateway **109**, **113**, and **117**. The administrator configures this parameter according to the capacity of cloud storage and the available network bandwidth for file transfer from the cloud gateway **109**, **113**, and **117**.

The administrator can adjust the amount of incoming and outgoing traffic for the cloud storage **107** based on the file transfer slot number. In the example of FIG. **8**, the variable of the file transfer slot number is set to two, indicating that the cloud storage **107** can process up to two HTTP connections/sessions simultaneously.

FIG. **9** illustrates an example of the structure of the file transfer priority information **412** of a file storage system, in accordance with an example implementation. The file transfer priority information **412** is implemented as a table in the example of FIG. **9**. Each row **901~903** of the table **412** represents a cloud gateway **109**, **113**, or **117**. Each row **901~903** may include an identifier of a cloud gateway **109**, **113**, or **117**, a priority calculated for each cloud gateway **109**, **113**, or **117**. In the example implementation, a higher value of this variable indicates a higher priority. The processes for calculating the priority may differ depending on the desire implementation. The file transfer priority information is indicative of time slot division.

The cloud storage **107** can utilize the file transfer priority information to store intermediate variables utilized for allocating a time slot for file transfer by each cloud gateway **109**, **113**, or **117**. In the example of FIG. **9**, the cloud gateway **109** named "cgw**0**" has higher priority, and the cloud gateway **113** and **117** has the same and lower priority, respectively.

FIG. **10** illustrates an example of the structure of the file transfer timing information **413** of a file storage system, in accordance with an example implementation. The file transfer timing information **413** is implemented as a table. Each row **1001~1003** of the table **413** represents a cloud gateway **109**, **113**, or **117**. Each row **1001~1003** may include an identifier of the cloud gateway **109**, **113**, or **117**, a time length allocated for correspond cloud gateway **109**, **113**, or **117**, a start time of the allocated time slot, an end time of the allocated time slot. The file transfer timing information may include multiple entries for multiple time slots (consecutive or non-consecutive), depending on the desired implementation.

The cloud storage **107** can utilize the file transfer timing information to store intermediate variables utilized for configuring the cloud gateway **109**, **113**, and **117**. In the example of FIG. **10**, the cloud gateway **109** named "cgw**0**", **113** named "cgw**1**", and **117** named "cgw**2**" are allocated with 24 hours of slot time, 12 hours of slot time, and 12 hours of slot time, respectively. The time lengths of the slots are weighted according to the priorities stored in the file transfer priority information **412**.

FIG. **11** illustrates an example of a flow diagram of the file transfer program **407** of the cloud storage **107** of a file storage system, in accordance with an example implementation. At the start of the flow diagram (**1101**), the file transfer program **407** selects the device that has the largest storage capacity from the cloud gateway configuration information **408**. The file transfer program then keeps the total size of storage components of the selected device as C_{MAX} (**1102**). When the total size is calculated for each cloud gateway **109**, **113**, or **117**, the sizes of the storage components that have an archiving flag activated are summed.

In the example of FIG. **11**, the rows **501** and **502** are used to calculate the total storage size of the cloud gateway **109** named "cgw**0**", and summed up to 10 TB. The storage sizes are calculated as C_0=10 TB for cloud gateway **109**, C_1=5 TB for cloud gateway **113**, and C_2=5 TB for cloud gateway **117**. The largest size is selected as $C_{MAX}=C_0$=10 TB.

The file transfer program **407** starts a loop for each cloud gateway **109**, **113**, or **117** (**1103**). In this loop, the file transfer program calculates a priority p_i for a cloud gateway **109**, **113**, or **117** according to the storage size of the corresponding cloud gateway by the following expression; $p_i=100\ C_i/C_{MAX}$ (**1104**). The priority is proportional to the storage size. In the example of FIG. **11**, the priorities are calculated as p_0=100, p_i=50, p_2=50 for cloud gateway **109**, **113**, and **117**, respectively as shown as FIG. **9**.

The file transfer program **407** calculates the time length allocated to the corresponding cloud gateway **109**, **113**, or **117** according to the above calculated priority by the following expression; $T_i=\alpha \cdot p_i\ T/\Sigma\ p_i\ (i=\{0, N-1\})$ (**1105**). The time length is proportional to the priority and the time length is multiplied by the file transfer slot number. In the example of FIG. **11**, the time lengths are calculated as T_0=24 hours, T_1=12 hours, T_2=12 hours for cloud gateway **109**, **113**, and **117**, respectively, as shown in FIG. **10**.

After finishing the calculation for all cloud gateways, the file transfer program **407** ends the loop for each cloud gateway (**1106**).

The file transfer program **407** decides on the start time of a time slot for each cloud gateway according to each time length (**1107**). The file transfer program aligns the time slots on the timeline in descending order of the time length of the time slot. Further, the file transfer program aligns multiple time slots simultaneously by the variable of the above a, the file maximum simultaneous flow number **411**.

After finishing the alignment of the time slots, the file transfer program **407** ends the flow diagram (**1108**).

Second Example Implementation

Access Rate Based Time Slot Allocation

In a second example implementation, a storage system allocates a time slot for each cloud gateway based on an access rate to the storage component of each cloud gateway.

FIG. **12** illustrates an example of the flow diagram of the file transfer program **407** in a second example implementation of a file storage system. In a second example implementation, the same network architecture as shown in FIG. **1** and the same hardware and software architecture as shown in FIG. **4** may be utilized, while inheriting the structure of the management information stored in the cloud storage.

The flow diagram is substantially similar to the first example implementation illustrated in FIG. **11** except with a different method to calculate the priorities of the cloud gateways **109**, **113**, and **117**. At the start of this flow diagram (**1201**), the file transfer program **407** selects the cloud gateway that has the largest write I/O frequency from the cloud gateway I/O statistics information **409** and keeps its variable as W_{MAX} (**1202**). Also, the file transfer program **407** calcu-

lates the priority p_i for each cloud gateway **109**, **113**, or **117** according to the write I/O frequency of the cloud gateway **109**, **113**, or **117** by the following equation; $p_i=100\ W_i/W_{MAX}$ (**1204**). The priority is proportional to the write I/O frequency.

Third Example Implementation

RTT Based Time Slot Allocation

In a third example implementation, a storage system allocates a time slot for each cloud gateway based on a round-trip time (RTT) between the cloud-storage device and each cloud gateway.

FIG. **13** illustrates an example of a message sequence in a third example implementation of a file storage system. In a third example implementation, the cloud storage **107** controls file transfer timing according to a RTT between the cloud storage **107** and a cloud gateway **109**, **113**, or **117**. The third example implementation also utilizes the same network architecture shown in the FIG. **1** and the same hardware and software architecture as shown in FIG. **4**, while also inheriting the structure of the management information stored in the cloud storage.

In the message sequence of FIG. **13**, after the installation of a cloud gateway **117** (**1301**), an administrator of the system configures the destination of file transfer by the installed cloud gateway (**1302**), and receives the configuration result (**1303**). Then the cloud gateway **117** sends an ICMP Echo request to the designated cloud storage **107** (**1304**) and receives an ICMP Echo reply (**1305**). According to the ICMP Echo reply from the cloud storage **107**, the cloud gateway **117** calculates an RTT (**1306**). The cloud gateway **117** sends a message submitting the calculated RTT to the cloud storage **107** (**1307**) and receives the result of the submission (**1308**). The remaining portions of the message sequence can be implemented similarly to FIG. **2**, depending on the desired implementation.

FIG. **14** illustrates an example of the flow diagram of the file transfer program **407** in a third example implementation of a file storage system.

The flow diagram is similar to the first example implementation illustrated in FIG. **11**, with a different method to calculate the priorities of the cloud gateways **109**, **113**, and **117**. At the start of the flow diagram (**1401**), the file transfer program **407** selects the cloud gateway that has the smallest RTT from the network RTT information **410** and keeps its variable as R_{MIN} (**1402**). The file transfer program **407** calculates the priority p_i for each cloud gateway **109**, **113**, or **117** according to the RTT of the cloud gateway **109**, **113**, or **117** by the following equation; $p_i=100\ R_{MIN}/R_i$ (**1404**). The priority is inversely proportional to the RTT.

Fourth Example Implementation

Separated Architecture

In a fourth example implementation, a storage system allocates a time slot as in the previous example implementations and includes, instead of the cloud-storage device, a file transfer manager which manages the configuration information of the cloud gateways and allocates the time slots for the cloud gateways. The file transfer manager may behave as a management unit for the cloud-storage device.

FIG. **15** illustrates an example of a network in a fourth example implementation of a file storage system. In addition to the components described in the first example implementation, a file transfer manager **121** is located in a cloud site **101** with the cloud storage **107**. The file transfer manager **121** is configured to be able to connect to the cloud storage **107** and cloud gateways **109**, **113**, and **117**. This example implementation illustrates an example of possible alternate system architecture. In this example implementation, the methods to control file transfer between the cloud gateway **109**, **113**, and **117** and the cloud storage **107** is processed by the file transfer manager **121**.

FIG. **16** illustrates an example of a message sequence in a fourth example implementation of a file storage system. The message sequence **1601-1611** is similar to that of FIG. **2**, with some differences. The differences with the example implementation shown in the FIG. **2** are that the cloud storage **107** in the FIG. **2** is changed to the file transfer manager **121**. Further, the administrator's configuration in the sequences **1602** and **1604** include not only a configuration of the destination of file transfer but also a configuration of an IP address of the file transfer manager **121** as the destination of the control path. The sequences **1604-1609** are processed with the file transfer manager **121**.

Furthermore, some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations within a computer. These algorithmic descriptions and symbolic representations are the means used by those skilled in the data processing arts to most effectively convey the essence of their innovations to others skilled in the art. An algorithm is a series of defined steps leading to a desired end state or result. In the example implementations, the steps carried out require physical manipulations of tangible quantities for achieving a tangible result.

Moreover, other implementations of the present application will be apparent to those skilled in the art from consideration of the specification and practice of the example implementations disclosed herein. Various aspects and/or components of the described example implementations may be used singly or in any combination. It is intended that the specification and examples be considered as examples, with a true scope and spirit of the application being indicated by the following claims.

What is claimed is:

1. A storage system communicatively coupled to a plurality of cloud gateways via a network, and configured to transfer data via the plurality of cloud gateways, the storage system comprising:

a memory configured to store information for each of the plurality of cloud gateways, the information indicative of traffic between the each of the plurality of cloud gateways and the storage system; and

a management unit that determines a priority for each of the plurality of cloud gateways based on the information indicative of the traffic between the each of the plurality of cloud gateways and the storage system, calculates time lengths weighted by the priorities of the each of the cloud gateways and multiplied by file transfer slots for each cloud gateway in a time period, and allocates time slots of the cloud gateways in the time period according to the calculated time lengths;

wherein the storage system is configured to conduct the allocation of the data transfer timing to each of the plurality of cloud gateways based on a maximum number of simultaneous sessions.

2. The storage system of claim **1**, wherein the information comprises a storage size of each of the plurality of cloud gateways.

3. The storage system of claim **1**, wherein the information comprises an access rate of each of the plurality of cloud gateways.

4. The storage system of claim 1, wherein the information comprises a round-trip time (RTT) between each of the plurality of cloud gateways and the storage system.

5. The storage system of claim 1, wherein the information is received from at least one of the plurality of cloud gateways.

6. The storage system of claim 1, wherein the management unit is in a management server.

7. A non-transitory computer readable storage medium storing instructions for executing a process, the instructions comprising:

storing information of each of a plurality of cloud gateways, the information indicative of traffic between the each of the plurality of cloud gateways and a storage system;

determining a priority for each of the plurality of cloud gateways based on the information indicative of traffic between the each of the plurality of cloud gateways and the storage system;

calculating time lengths weighted by the priorities of the each of the cloud gateways and multiplied by file transfer slots for each cloud gateway in a time period, and

allocating time slots of the cloud gateways in the time period according to the calculated time lengths;

wherein the allocating the data transfer timing to each of the plurality of cloud gateways is based on a maximum number of simultaneous sessions.

8. The non-transitory computer readable storage medium of claim 7, wherein the information comprises a storage size of each of the plurality of cloud gateways.

9. The non-transitory computer readable storage medium of claim 7, wherein the information comprises an access rate of each of the plurality of cloud gateways.

10. The non-transitory computer readable storage medium of claim 7, wherein the information comprises a round-trip time (RTT) between each of the plurality of cloud gateways and a storage system.

11. The non-transitory computer readable storage medium of claim 7, wherein the information is received from at least one of the plurality of cloud gateways.

12. A method of managing a plurality of cloud gateways, comprising:

storing information of each of the plurality of cloud gateways, the information indicative of traffic between the each of the plurality of cloud gateways and a storage system;

determining a priority for each of the plurality of cloud gateways based on the information indicative of traffic between the each of the plurality of cloud gateways and the storage system;

calculating time lengths weighted by the priorities of the each of the cloud gateways and multiplied by file transfer slots for each cloud gateway in a time period, and;

allocating time slots of the cloud gateways in the time period according to the calculated time lengths;

wherein the allocating the data transfer timing to each of the plurality of cloud gateways is based on a maximum number of simultaneous sessions.

13. The method of claim 12, wherein the information comprises a storage size of each of the plurality of cloud gateways.

14. The method of claim 12, wherein the information comprises an access rate of each of the plurality of cloud gateways.

15. The method of claim 12, wherein the information comprises a round-trip time (RTT) between each of the plurality of cloud gateways and a storage system.

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